To be presented at the Meeting on
Miniaturization of High Energy Physics Detectors
Pisa, Italy, September 18-20, 1980

OG 561

CONF-800976--1

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Microchannel Plate as a Detector of Minimum Ionizing Particle

K. Oba¹, P. Rehak, S.D. Smith

Brookhaven National Laboratory, Upton, N.Y. 11973

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¹Permanent address: Hamamatsu TV Co., Ltd., Japan

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I. Introduction

The performance of the micro-channel plate electron multiplier as a detector of the minimum ionizing particles was investigated using 3 GeV negatively charged particles and 7 GeV protons. Special attention was directed towards i) a detection efficiency measurement, and ii) a study of timing properties. From the above measurement we have investigated the feasibility of using MCP as an active target with a good spatial and time resolution.

A cross section of the MCP-detector is shown in Fig. 1. The principle of the detection is illustrated in Fig. 2. It shows a small cross section of the MCP detector. A fast particle penetrating the plate crosses a large number of channel walls. If a secondary electron is emitted and goes into the channel, it can generate an electron avalanche in subsequent stages of the detector. The multiplication process in MCP retains the spatial information so the track image can be made visible on the phosphoric anode.

As is well known, the electron transit time in micro-channel plate is very short and, consequently, the detector can in principle handle very high rates.

II. Efficiency Measurement

The measurement was performed at the D-4 test beam at the Brookhaven AGS. The beam was defined by 5 scintillator counters, one anti-counter and two Cerenkovs. Cerenkov counters were used to veto electrons in the beam. One of the scintillators (just next to MCP detector under study) was a .5 mm

thin finger counter defining the beam position. The typical pulse height distributions at the anode produced by the minimum ionizing particles are shown in Fig. 3b. Note the difference between the above distributions and distributions obtained by exciting MCP with UV light (Fig. 3a). We think the origin of the first electron is responsible for the difference.

The detection efficiencies in 1, 2 and 3 stage MCP as a function of the applied voltage are shown in Fig. 4 for particles incident at an angle of 18° . Increasing the number of MCP's increased the detection efficiency, which reached $\sim 90\%$.

The dependence of the detection efficiency on the angle of the particle incident was investigated. The path length within the MCP traversed by the particles is inversely proportional to $\sin\alpha$ and we will assume that the mean number of secondary electrons produced by the particle is proportional to the path length. According to this simplified model the detection efficiency can be expressed by the formula:

$$\epsilon = 1 - e^{-k/\sin\alpha}$$

The inefficiency of the detector ($1 - \epsilon$) is plotted as a function of ($1/\sin\alpha$) in Fig. 5. Assuming the Poissanian statistic in the number of secondary electrons produced by a relativistic particle, the mean number of secondary electrons can be calculated. Knowing the length to the diameter ratio of the target microchannel plate this number can be translated into the probability of the emission of the secondary electron from the wall into the channel. This probability is about .6% for the microchannel plate under study.

III. Study of Timing Properties

The output waveform of the current from the detector anode adiabatically matched into 50Ω coaxial geometry is shown in Fig. 6. Fig. 6a shows the waveform from the one stage MCP detector, Fig. 6b the waveform from the three-stage detector, both excited by a passage of the minimum ionizing particle. (Note the different horizontal scales 500 ps and 2 ns/div, respectively.) The rise time is in subnanosecond region.

The transit time jitter for the MCP detectors was determined from timing measurements of two MCP detectors and a scintillator coupled to a conventional PMT. The experimental set-up is shown in Fig. 7a. From the relative timing distributions (start-stop) obtained in the three different combinations of two out of the three detectors, the intrinsic transit time jitter of the two MCP detectors could be calculated. It was found to be $\text{FWHM} = 180$ ps for 2-stage MCP and $\text{FWHM} = 260$ ps for 3-stage detector. Fig. 7b shows the distribution of the time jitter between two MCP-detectors on the logarithmical scale. We can see the gaussian character of the distribution down to 10^{-4} level.

IV. MCP as a Track Sensitive Target

We have used the Rutgers University optical set-up at the AGS A-2 beam to obtain some pictures of the phosphor screen of the MCP detector. The detailed description of the optical system can be found elsewhere.⁽¹⁾

The examples of the images recorded on film are shown in Fig. 8. (Relatively bit spot size of the track images shown is due to the spread of the electrons between the end of the MCP and the phosphor screen. This spread can be reduced down to a $\approx 10\mu$ level by using the correct focussing.)

V. Conclusion

The present work indicates that MCP has the possibility to detect the minimum ionizing particles with the time resolution of $\sigma \approx 100$ ps and with the spatial resolution of ≈ 10 -20 μ .

To make the detector more useful a substantial improvement in the detection efficiency is necessary. We continue to try to solve this problem.

This research was supported by the US Department of Energy under contract No. DE-AC02-76CH00016.

References

1. D.M. Potter, Two New Triggerable Track Chambers - Targets, Rutgers University Preprint, RU-80-223.

Fig. 1 Cross-sectional view of the 3-stage MCP detector used as a minimum ionizing particle detector.

Fig. 2 Schematic cross-section of a three-stage MCP detector and an interaction produced by a charged particle.

(a) 3.2kV 3.3kV 3.4kV 3.5kV 3.6kV 20ch/div

(b) 3.2kV 3.4kV 3.6kV 2500/div
20ch/div
1ch=1pc

Fig. 3 PHD of the 3-stage MCP detector stimulated by (a) UV-light and (b) minimum ionizing particles.

Fig. 4 Detection efficiency of the three kinds of the MCP detector as a function of the applied voltage.

Fig. 5 Inefficiency of the MCP detectors as a function of incident angle.

a.

b.

Fig.6. Anode current waveform from
 a) Single stage MCP detector.
 b) 3 - stage MCP detector.

Fig. 7a Schematic view of the experimental set-up used in the timing test of the MCP detectors.

Fig. 7b.

Distribution of time differences between two MCP detectors on the log. scale.
 1 channel = 40 ps.
 1 div = factor of 10

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9/3/80

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Brookhaven National Laboratory, Upton, N.Y. 11973

ABSTRACT

Micro-channel plate multipliers have been used to detect the passage of relativistic charged particles. Measurements of the detection efficiency and pulse height response versus micro-channel plate gain are presented for one, two and three micro-channel plate arrays.

The probability of detecting an avalanche on the detector anode per one channel of MCP crossed by the relativistic particle was calculated.

Temporal response and time jitter were measured and are reported.

The track images of beam particles crossing the detector are shown.

¹Permanent address: Hamamatsu TV Co., Ltd., Japan